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Recompact Iowa Soil Materials Before Using as Liners for Waste Containment[1]

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Soil materials are often used in hazardous-waste disposal facilities to provide a physical barrier to leachate movement. Both existing soils and recompacted soil materials have been used in barrier construction. Solute transport experiments and measurements of saturated hydraulic conductivity were used to characterize the solute transport properties of three Iowa soil materials. Experiments were carried out by using undisturbed soil samples as well as recompacted samples. The experimental results show that recompaction greatly altered the solute transport properties of the three soil materials. It is concluded that recompaction is necessary for any of these materials to satisfy Environmental Protection Agency standards for barriers in hazardous-waste landfills and surface impoundments.
INDEX DESCRIPTORS: hazardous waste, hydraulic conductivity, solute transport, breakthrough curves

At present, disposing of hazardous waste ultimately involves storage in a hazardous-waste disposal facility. Such facilities include landfills, surface impoundments, evaporation ponds, and sludge ponds among others. Ideally, wastes should be stored so that they remain isolated from the environment. This ideal has been difficult, if not impossible, to achieve in practice. Media reports and hazardous-waste literature are rich with examples of the inability to completely isolate wastes.

Though complete isolation of wastes may not be possible, storage with minimal environmental pollution is possible if hazardous-waste disposal facilities are properly designed and constructed; however, much work remains to be done before optimal design and construction procedures are identified. There is a need for such information in anticipation of measures that will have to be taken to manage wastes generated in this state (Iowa Department of Water, Air and Waste Management, 1985; Iowa Department of Natural Resources, 1987).

Soil materials are often used in hazardous-waste disposal facilities to provide a physical barrier to the flow of contaminated water or other liquid contaminants. These materials are sometimes recompacted to form a liner several feet thick at the base of, or as a cover to, the impounding facility (Fung, 1980; Mutch, 1981; Slimak, 1978). In other instances, recompaction is not necessary. Fung (1980) presents data indicating that existing soils or existing geologic materials have been used in many applications.

Both these types of barriers can limit leachate movement if the correct soil or geologic material is chosen and if the structure of the material is such that it displays the desired hydraulic properties. Barriers limit leachate movement because of hydraulic transport properties that result in extremely small leachate fluxes. Transport properties are not only determined by the types of soil particles present, but also are influenced to a large extent by the arrangement and organization of the pore space amongst the particles. In recompacted soil material, leachate is constrained to move through the pores of a relatively uniform matrix of densely packed, fine particles. In an existing soil, aggregation of particles and the activity of plant roots, earthworms, and other biota can cause preferential flow pathways that allow leachate to move rapidly through the soil, bypassing much of the soil matrix. Net transport of leachate in such a situation can be orders of magnitude greater than where no preferential pathways exist. In considering materials for use in barrier construction, it is imperative that the transport properties of the proposed material be thoroughly investigated in precisely the same structural state as that of the completed barrier. If leachate transport is greater than desired, compaction will be needed to destroy pathways of preferential flow.

At present, little information is available regarding soil materials in Iowa that could be used for barrier construction. McBride et al. (1987) published information on the physical properties of three Iowa soils that are likely candidates for use in barrier construction. They used this information to determine which of these materials is best suited for use as a barrier when compacted to maximum density. The present paper continues the evaluation of the same three materials by using simple solute transport experiments and measurements of saturated hydraulic conductivity to characterize the transport properties of recompacted soil samples and undisturbed soil samples. These measurements not only add to the data base of Iowa soil properties, but also serve to demonstrate the influence and importance of compaction in barrier construction.

MATERIALS AND METHODS

Samples of B horizon soil were taken from depths of 60 to 120 cm in soils formed from till, loess, and paleosol parent materials. The till-derived soil was sampled in a Nicollet map unit and was a fine-loamy, mixed, mesic Aquic Hapludoll. The loess-derived soil was Fayette, a fine-silty, mixed, mesic Typic Hapludalf. Clarinda, an exhumed paleosol, is a fine, montmorillonitic, mesic, sloping Typic Argiaquoll. McBride et al. (1987) present information on sampling locations and a more detailed description of these soils. Samples were air-dried, ground, and passed through a 2-mm sieve.

At each location, columns of undisturbed soil were also collected by using a 6.5-cm-diameter hydraulically driven tube. The columns were segmented into 7.6-cm cores that were placed in plastic bags and stored at 4°C.

The ground and sieved materials were wetted to water contents 1 to 2% above optimum for maximum compaction and recompacted in standard compaction permeameters (10.2 cm in diameter and 11.6 cm long) by using information from Proctor moisture-density tests (McBride et al., 1987). Three replicates of each soil material were recompacted to maximum density by following the methods used in ASTM Test D-698-78, Method A (1982).

The undisturbed cores were placed inside cylinders 7.62 cm in diameter and 7.62 cm long. The gap between the core and cylinder wall was filled with successive layers of paraffin wax after testing with dyes showed this technique effective in preventing flow along the cylinder walls. An acrylic permeameter was designed to contain the

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encased soil cores. Three replicate undisturbed cores were prepared for each soil material.

Saturated hydraulic conductivities of both the undisturbed cores and recompacted samples were measured by using a constant-head method (Klute, 1965). To reduce air entrapment, the soil pores were filled with water by introducing a saturated $CaSO_4$ solution at the base of the permeameters. Once saturated, steady flow was obtained by passing several pore volumes of the $CaSO_4$ solution through each permeameter. Conductivities of the recompacted materials were determined by using hydraulic gradients of 170 to 270 m/m. Conductivites of the undisturbed materials were determined by using hydraulic gradients of 0.16 to 31 m/m.

Solute breakthrough experiments were conducted after each determination of hydraulic conductivity. A 0.05*N* $CaCl_2$ tracer solution was exchanged for the $CaSO_4$ solution to start each experiment. Steady flow was obtained throughout each experiment by maintaining the same hydraulic gradient as for the conductivity measurement. Beginning with the introduction of the chloride tracer, volume increments of column effluent were collected by using a fraction collector. Chloride concentrations were determined by constant-potential coulometry.

The soil samples were visually inspected at the conclusion of the experiments. In all the undisturbed samples, root holes, fractures, earthworm channels, or other such openings were visible to some degree to the naked eye. No such visible flow pathways were observed in the recompacted samples.

RESULTS AND DISCUSSION

Saturated hydraulic conductivity is a major criterion presently used to characterize the effectiveness of a barrier (Grube et al., 1987). Hydraulic conductivity is not an explicit measure of the rate at which solutes move through soil (Horton et al., 1987), but it does provide useful information because solute movement is intimately coupled with water flow. The saturated hydraulic conductivities of the undisturbed and recompacted samples of till, loess, and paleosol materials are presented in Table 1. These data make it clear that recompaction changed the dynamics of water flow in each soil material. Recompaction eliminated the pores and flow pathways through which water could flow with little resistance. The effect of recompaction on conductivity was orders of magnitude greater than the influences of soil material or the variability among replicates.

For hazardous-waste landfills and surface impoundments, the Environmental Protection Agency (EPA) requires liners to have conductivities less than 1×10^{-9} $m^3/(m^2s)$. Table 1 shows that recompaction was needed for all three Iowa soil materials to meet the EPA criterion.

The results of the solute transport experiments are shown in the breakthrough curves of Figure 1. Each graph shows breakthrough curves for three undisturbed samples and three recompacted samples.

Table 1. Saturated hydraulic conductivities for three replicates of recompacted and undisturbed Nicollet (till), Fayette (loess), and Clarinda (paleosol) samples.

Soil	Material	*Hydraulic Conductivity* $(m^3/(m^2s))$ I	II	III
Nicollet	Recompacted	5.47×10^{-11}	6.58×10^{-11}	1.22×10^{-10}
	Undisturbed	4.93×10^{-6}	4.35×10^{-6}	6.36×10^{-6}
Fayette	Recompacted	2.84×10^{-10}	2.67×10^{-10}	2.61×10^{-10}
	Undisturbed	2.47×10^{-4}	9.56×10^{-5}	2.96×10^{-5}
Clarinda	Recompacted	4.18×10^{-11}	2.97×10^{-11}	5.05×10^{-11}
	Undisturbed	1.63×10^{-7}	6.27×10^{-7}	2.47×10^{-6}

The relative effluent concentration represents the concentration of a particular volume increment of effluent relative to the concentration of tracer solution introduced at the sample's surface. The relative pore volume represents the cumulative volume of effluent collected relative to the total soil pore volume and may be thought of as scaled time. Measurements of bulk density, and particle density data from McBride et al. (1987) were used to calculate the total pore volume of each sample.

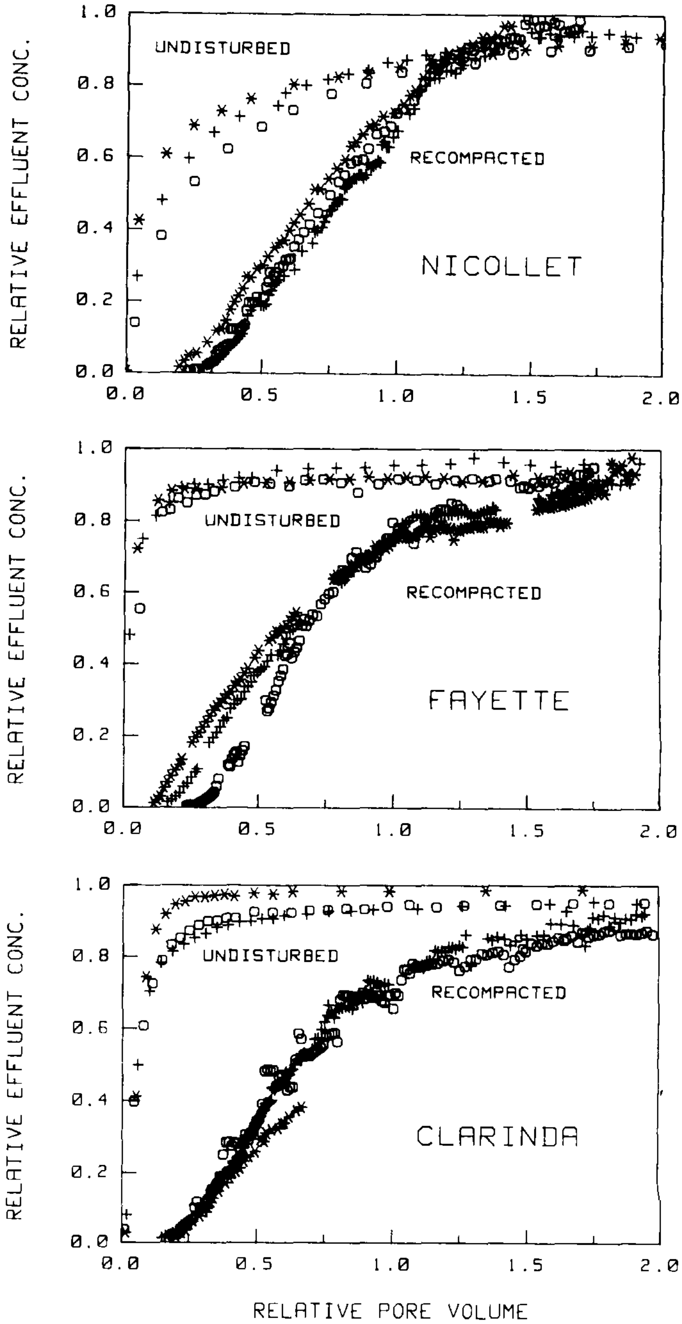

Fig. 1. Solute breakthrough for three replicates of recompacted and undisturbed Nicollet (till), Fayette (loess), and Clarinda (paleosol) samples.

The results in Figure 1 demonstrate that the effect of recompaction on solute transport overshadowed the influences of soil material and sample variability. For the undisturbed samples, the shapes of the breakthrough curves are similar for all three soil materials, and the variability among replicates is relatively small. The same is true for the recompacted samples.

Recompaction significantly altered tracer movement in these experiments. In the experiments with the undisturbed samples, tracer appeared almost instantaneously in the sample effluent, and concentrations rose quickly to values near maximum. In the experiments with recompacted samples, 0.1 to 0.3 pore volumes of effluent were collected before tracer began to appear. Once present, concentrations increased more slowly than observed for the undisturbed samples. In terms of disposal facility barriers, the most important point to observe from these data is that tracer appeared in the column effluents of the undisturbed samples long before it appeared in the effluents of the recompacted samples. These differences are important because a barrier is considered as failed at the time leachate first appears at the bottom of the barrier.

A difficulty that arises in examining these differences is that leachate transport in an actual field-scale barrier will differ from that in a laboratory column. In particular, from solute transport theory, it is known that the slopes of the curves in Figure 1 will vary slightly when extrapolated to field conditions. For this reason, it is not particularly useful to precisely calculate the differences in times (relative pore volumes) of first breakthrough. It is enough to point out that, for all three soil materials, times of first breakthrough were significantly delayed for the recompacted samples.

The results of the solute transport experiments reinforce those of the hydraulic conductivity measurements. Recompaction changed the dynamics of water and solute transport for each soil material by eliminating pores and pathways through which water and solute could flow with little resistance.

In summary, the experimental results show that recompaction was needed for all three Iowa soil materials to meet the EPA barrier criterion. The experimental results clearly show that recompaction improved the ability of each of these materials to reduce the rate of leachate transport. This work also illustrates that the influence of soil structure on transport properties must be thoroughly examined to determine how well a barrier will perform in reducing rates of transport.

The three soil materials evaluated in this study were chosen to be broadly representative of major soil materials in Iowa. Although the data may be useful to indicate expected properties of soils similar to those investigated, the data should not be extrapolated and used in actual design situations.

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REFERENCES

ASTM D-698-78 Method A. 1982. Standard test methods for moisture-density relations of soils and soil-aggregate mixtures using 5.5-lb (2.49-kg) rammer and 12-in. (305-mm) drop. p. 202-208. *In* Annual Book of ASTM Standards, Part 19, Natural Building Stones; Soil and Rock. American Society for Testing and Materials, Philadelphia, PA.

FUNG, R. 1980. Liner case studies, p. 146-183. *In* Protective barriers for containment of toxic materials. Pollution technology review no. 66. Noyes Data Corporation, Noyes Building, Park Ridge, NJ.

GRUBE, Jr., W.E., M.H. ROULIER, and J.G. HERRMANN. 1987. Implications of current soil liner permeability research results. p. 9-25. *In* Land Disposal, Remedial Action, Incineration and Treatment of Hazardous waste. Proc. 13th Annu. Res. Symp., Cincinnati, Ohio. May 6 - May 8, 1987. EPA/600/9-87/015, U.S. Environmental Protection Agency, Cincinnati, Ohio.

HORTON, R., M.L. THOMPSON, and J.F. MCBRIDE. 1987. Method of estimating the travel time of noninteracting solutes through compacted soil material. Soil Sci. Soc. Am. J. 51:48-53.

IOWA DEPARTMENT of WATER, AIR and WASTE MANAGEMENT. 1985. Hazardous waste management plan. Des Moines, Iowa.

IOWA DEPARTMENT of NATURAL RESOURCES. 1987. Plan for a hazardous waste storage facility in Iowa. Des Moines, Iowa.

KLUTE, A. 1965. Laboratory measurement of hydraulic conductivity of saturated soil. *In* C.A. Black et al. (ed.) Methods of soil analysis. Agronomy 9:210-221.

MCBRIDE, J.F., R. HORTON, and M.L. THOMPSON. 1987. Evaluation of three Iowa soil materials as liners for hazardous-waste landfills. Proc. Iowa Acad. Sci. 94:73-77.

MUTCH, Jr., R.D. 1981. Secure burial of hazardous wastes: A state-of-the-art example. p. 116-122. *In* J.P. Collins and W.P. Saukin (ed.) The hazardous waste dilemma: Issues and solutions. American Society of Civil Engineers, New York, NY.

SLIMAK, K.M. 1978. Landfill disposal systems. Environ. Health Perspect. 27:309-316.